Modeling the Impact of Seascape Evolution on the Seismic Response of Shelf and Slope Strata

Lincoln F. Pratson
Division of Earth and Ocean Sciences
Duke University
Durham, NC 27708-0230
phone: (919) 681-8077 fax: (919) 684-5833 email: lincoln.pratson@duke.edu

Award Number: N000140310141
http://www.geo.duke.edu/faculty/pratson.htm

LONG-TERM GOALS

My long-term goals are to improve our understanding of the morphologic and stratigraphic evolution of the continental shelf and slope, and to enhance our ability to extract geologic information about these regions from geophysical data of them.

OBJECTIVES

The specific objectives of this project are to:

(1) Model the potential changes to the seismic response of the seabed offshore of river mouths caused by flood sedimentation and storm reworking (addresses EuroSTRATAFORM Task D2).
(2) Constrain the time and space scales over which different shelf and slope processes produce a stratigraphic record that is detectable in seismic reflection data (addresses EuroSTRATAFORM Task D5).
(3) Model what is and is not preserved of the stratigraphic record across continental shelves and slopes over geologic time (addresses overarching goal of EuroSTRATAFORM).

APPROACH

While seldom resolved in seismic reflection data, flood deposits have the potential to modify the seismic response of the seabed offshore of rivers by altering the physical properties of the surface such as grain size distribution, bulk density and porosity. We (I along with my EuroSTRATAFORM collaborators James Syvitski and Eric Hutton [INSTAAR]) are assessing the acoustic significance of such changes (objective #1) by simulating the evolution of flood-derived strata and the variation in the seabed reflectivity and attenuation of these strata over time for the shelf region offshore of two Italian rivers in the western Adriatic; the Po and Pescara. The simulations are being carried out by coupling the sediment discharge model HYDROTREND (Syvitski and Moorhead, 1999) with the sedimentary-process/stratigraphic model SEDFLUX2D (Syvitski and Hutton, 2001), the acoustic velocity and attenuation models of Biot (1962a,b) and Buckingham (1997, 1998, 2000), and a convolution model for simulating normal incident seismic reflection data (e.g., Pratson and Gouveia, 2002).

This same set of simulations is also being used to address the time and space scales over which flood sedimentation and, to a lesser degree storms, produce shelf strata that are detectable in seismic reflection data (objective #2). The additional step being used here is to evaluate the number and

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Modeling the Impact of Seascape Evolution on the Seismic Response of Shelf and Slope Strata**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Duke University,,Division of Earth and Ocean Sciences,,Durham,,NC,27708**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
My long-term goals are to improve our understanding of the morphologic and stratigraphic evolution of the continental shelf and slope, and to enhance our ability to extract geologic information about these regions from geophysical data of them.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

magnitude of depositional events required to produce changes in the pattern of subbottom reflectors as recorded in common types of high-frequency seismic reflection data (e.g., 3.5 kHz, airgun, watergun and CHRIP data).

The third objective, relating sedimentary processes to shelf and slope strata formation over geologic time, is being approached out by using SEDFLUX2 to simulate the evolution of a generalized passive margin while recording deposition and erosion across the margin during the course of the simulation. This bookkeeping will enable us (Hutton, Syvitski and I) to track where sediments get deposited by what processes and what fraction of the sediments then get moved under what conditions before they eventually become part of the stratigraphic record.

WORK COMPLETED

The first stratigraphic simulations of flood-derived strata off the Po and Pescara Rivers have been completed. To do this, SEDFLUX2 was first upgraded to incorporate a near-shore shelf reworking module (Storms, 2003), and a fluvial erosion/deposition module (Paola, 1992). Two one-hundred year long simulations have been generated for each river based on HYDROTREND predictions generated by A. Kettner [INSTAAR]. The Po simulations, which are for the last glacial maximum (LGM) versus the present environment, examine the impact of varying drainage basin area on flood sedimentation (in this case due to differences in sea level). The Pescara simulations are for the pre- and post-emplacement of dams on the river, and address the impact of flow regulation on sedimentation offshore of such rivers.

The upgraded version of SEDFLUX2 has also been used to complete the stratigraphic simulations of generalized passive margin evolution by various sedimentary processes. The first of these are control simulations, which predict shelf-slope strata formation and preservation under the action of first order processes such as uniform sediment supply, sea level variations and subsidence. These simulations reproduce the results of earlier, more geometric-based stratigraphic models. The remaining simulations incorporate a broader range of processes, such as floods, waves, slope failures and gravity flows, and so demonstrate how these processes may affect and thus bias what gets preserved in the shelf-slope stratigraphic record.

RESULTS

The simulations of strata formation off both the Po and Pescara Rivers predict thicker, coarser-grained flood deposits that extend farther offshore of the rivers as their sediment discharge increases. Flood deposits offshore of the Po are predicted to be more substantial during the LGM when lowered sea level increased the drainage basin area of the river to roughly twice its present size. The Pescara simulations suggest that dam emplacement has significantly reduced the coarseness and total amount of sediment being deposited offshore of the river, a change that should be marked by an abrupt upwards transition from coarser, more heterogeneous pre-dam strata to finer, homogeneous post-dam strata (Figure 1). The impacts of these sedimentologic changes on the acoustic character of the seabed are now being modeled.

The more general simulations of process-driven strata formation on shelves and slopes are showing that certain facies are consistently eroded and so are poorly preserved in shelf-slope strata. This is particularly true of shore-face sediments. These are eroded (1) by rivers during relative falls in sea level, and (2) by ocean storms during relative falls *and* rises in sea level.

IMPACT/APPLICATIONS

(1) The modeling of strata formation off the Po and Pescara Rivers is anticipated to at least theoretically constrain the impact of individual flood events on the acoustic response of the seabed offshore of rivers with significant sediment discharges.

(2) This same modeling should also theoretically constrain the time and space scales overwhich multiple flood events produce strata that are measurable in high-resolution sonar and seismic reflection data.

(3) The more general modeling of process-driven strata formation should significantly enhance our appreciation how much of the total sediment load to any point across a shelf and slope ultimately gets preserved in the strata at that location. In turn, this information will help establish what hope exists for successfully inverting the stratigraphic record at points along the shelf and slope for the processes that created it.

RELATED PROJECTS

I am continuing to work with Dr. Dave Cacchione (CME) on the relationship between the dynamics of internal waves and the gradients of the continental slopes. We are presently working on a draft of a manuscript that will appear in American Scientist. I am also continuing to work on the 2D modeling of subaqueous debris flows with Dr. Jim Buttles (MIT), a project in which we are presently simulating a well documented debris flow that happened in Lake Melville. And I am finalizing my laboratory study with Dr. Jeff Marr (SAFL, Uminn) on the transition between debris flows and turbidity currents. All of the above are projects initiated during or following STRATAFORM.

REFERENCES

Biot, M.A., 1962a, Mechanics of deformation and acoustic propagation in porous dissipative media: Journal of Applied Physics, v. 33, p. 1482-1598.

Biot, M.A., 1962b, Generalized theory of acoustic propagation in porous dissipative media: Journal of the Acoustical Society of America, v. 34, p. 1254-1264.

Buckingham, M.J., 1997, Theory of acoustic attenuation, dispersion, and pulse propagation in unconsolidated granular materials including marine sediments: Journal of the Acoustical Society of America, v. 102, p. 2579-2596.

Buckingham, M.J., 1998, Theory of compressional and shear waves in fluidlike marine sediments: Journal of the Acoustical Society of America, v. 103, p. 288-299.

Buckingham, M.J., 2000, Wave propagation, stress relaxation, and grain-to-grain shearing in saturated, unconsolidated marine sediments: Journal of the Acoustical Society of America, v. 108, p. 2796-2815.

Pratson, L.F., and W. Gouveia, 2002, Seismic modeling of experimental strata: American Association of Petroleum Geologists Bulletin, v. 86, p. 129-144.

Syvitski, J.P.M., and M.D. Moorehead, 1999, Estimating river-sediment discharge to the ocean: application to the Eel margin, northern California: Marine Geology, v. 154, p. 13-28.

Syvitski, J.P.M., and E.W.H. Hutton, 2001, 2D SEDFLUX1.0C: an advanced process-response numerical model for the fill of marine sedimentary basins: Computers & Geosciences, v. 27, p. 731-754.

FY03 PUBLICATIONS

Pratson, L.F., A. Stroujkova, D. Herrick, F. Boadu, and P. Malin, *in press*, Predicting seismic velocity and other rock properties from clay/mud/shale content only: *Geophysics*.

Pratson, L.F., and D. Cacchione, 2002 (abs), An open-ocean wide analysis of the slope of the continental slope and internal tides: *Eos Trans. AGU, v. 83*.

Cacchione, D., and L. Pratson, 2003 (abs), Internal waves and sedimentation on continental margins: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts, v. 5*.

Marr, J., and L. Pratson, 2003 (abs), Experimental study of subaqueous, clay-rich, gravity flows: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts, v. 5*.

Strong, N., J.J. Fedele, C. Paola, and L. Pratson, 2003 (abs), An experimental study at basin scale of valley incision and associated deposition during base-level fluctuations: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts, v. 5*.

Wolinsky, M.A., and L. Pratson, 2003 (abs), Overpressure development during siliclastic passive margin evolution: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts, v. 5*.

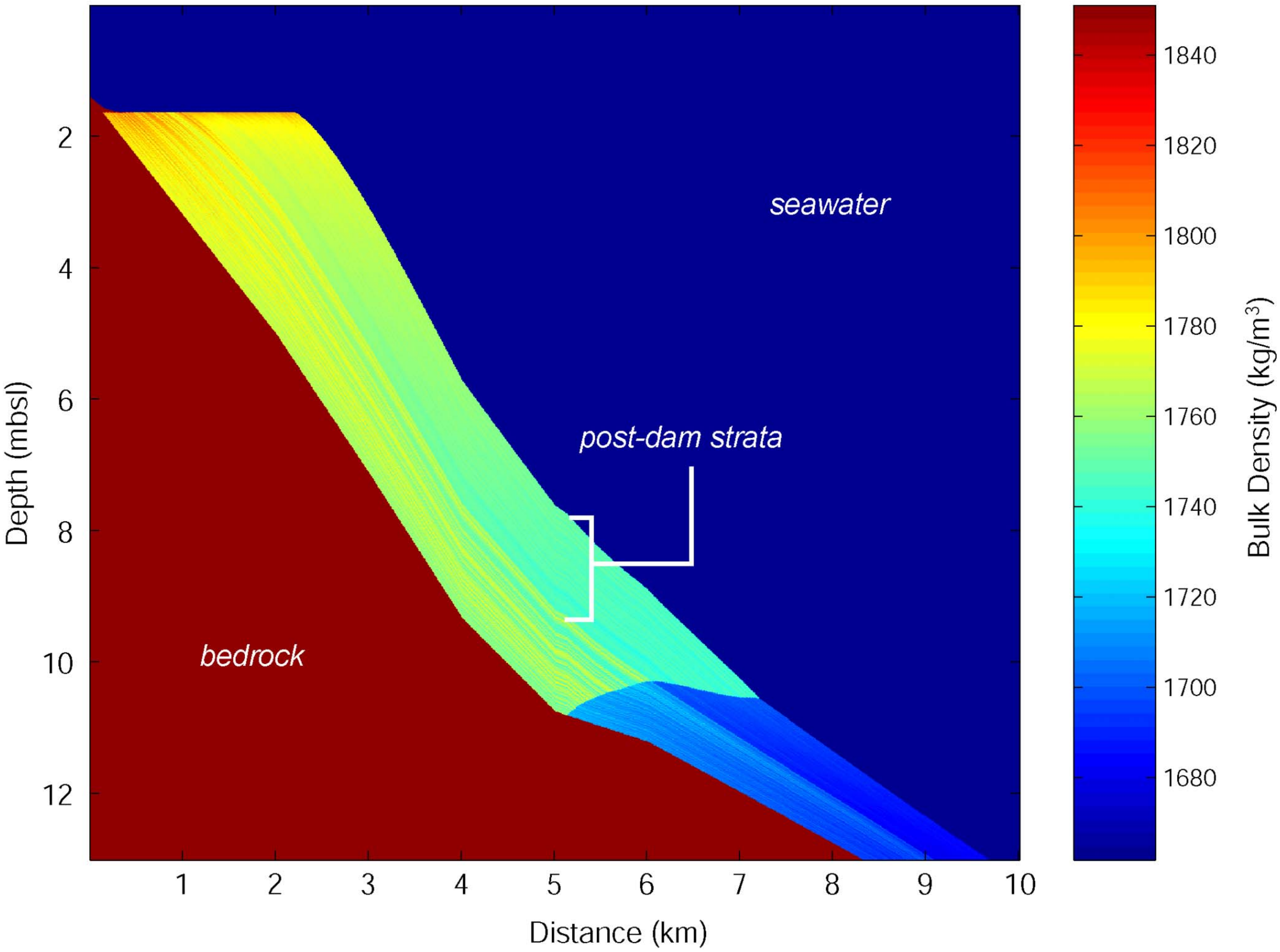

Figure 1. SEDFLUX simulation of flood-derived strata formed offshore the Pescara River, western Adriatic, before and after dams were emplaced along the river. [Note the lower bulk densities of the post-dam strata, which should be manifest in the acoustic response of these strata.]